

**ANNUAL REPORT  
ON THE  
JPL LONG-TERM QUARTERLY  
GROUNDWATER MONITORING PROGRAM  
JANUARY 2002 TO NOVEMBER 2002**

*Prepared for the:*

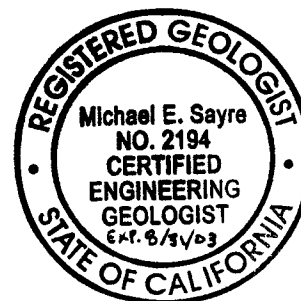
**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
JET PROPULSION LABORATORY**

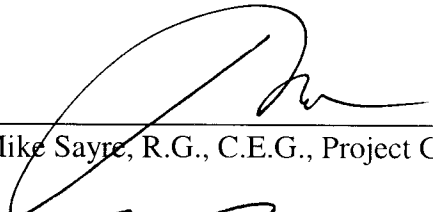
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Version: Final  
May 27, 2003

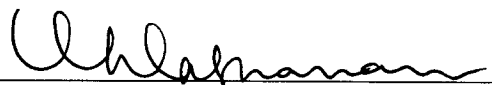


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## TABLE OF CONTENTS

| Section   | Page |
|---|------|
| ACRONYMS AND ABBREVIATIONS.....                                     | vii  |
| EXECUTIVE SUMMARY .....   | ix   |
| 1.0 INTRODUCTION.....   | 1    |
| 2.0 SAMPLING AND FIELD QUALITY ASSURANCE/QUALITY CONTROL .....      | 4    |
| 2.1 Shallow Monitoring Wells.....                                   | 4    |
| 2.2 Deep Multi-Port Monitoring Wells.....                           | 4    |
| 2.3 Quality Assurance/Quality Control Procedures.....               | 4    |
| 3.0 ANALYTICAL RESULTS - CONSTITUENTS OF INTEREST .....             | 6    |
| 3.1 Volatile Organic Compounds Results.....                         | 6    |
| 3.2 Perchlorate Results.....  | 8    |
| 3.3 1,4-Dioxane and NDMA Results .....                              | 8    |
| 3.4 Metals Results.....   | 8    |
| 3.5 Production Well Data.....                                       | 9    |
| 3.6 Summary of Results.....   | 10   |
| 4.0 GENERAL WATER CHEMISTRY .....                                   | 11   |
| 5.0 WATER-LEVEL MEASUREMENTS .....                                  | 12   |
| 6.0 MONITORING PROGRAM EVALUATION.....                              | 13   |
| 6.1 Modification of Sampling Frequency for Plume Analytes .....     | 14   |
| 6.2 Modification of Sampling Frequency for Non-Plume Analytes ..... | 14   |
| 7.0 CONCLUSIONS AND RECOMMENDATIONS.....                            | 16   |
| 8.0 REFERENCES .....  | 19   |

## **TABLES**

|           |  |
|-----------|--|
| Table 1-1 | Summary of Well Construction Details for JPL Groundwater Monitoring Wells                                |
| Table 1-2 | Summary of Analyses Performed During the Sixth Year of Long-Term Quarterly Groundwater Monitoring at JPL |

|           |  |
|-----------|--|
| Table 3-1 | Summary of Volatile Organic Compounds and Perchlorate Detected During the First Six Years of Long-Term Quarterly Monitoring at JPL         |
| Table 3-2 | Summary of Metals Detected During the First Six Years of Long-Term Quarterly Groundwater Monitoring at JPL                                 |
| Table 3-3 | Summary of Volatile Organic Compounds and Perchlorate Reported in Groundwater at Municipal Production Wells near JPL through November 2002 |
| Table 4-1 | Summary of Water-Chemistry Results from Groundwater Samples Collected from JPL Monitoring Wells, January-February 2002                     |
| Table 4-2 | General Water Types Observed During the First Six Years of Long-Term Quarterly Monitoring at JPL   |
| Table 5-1 | Water-Level Elevations for JPL Groundwater Monitoring Wells, January 2002 to November 2002   |
| Table 6-1 | Well/Screen Classifications for JPL Groundwater Monitoring Wells, Volatile Organic Compounds   |
| Table 6-2 | Well/Screen Classifications for JPL Groundwater Monitoring Wells, Perchlorate  |
| Table 6-3 | Comparison of Existing and Recommended Monitoring Frequencies for the JPL Groundwater Monitoring Program                                   |

## **FIGURES**

|            |   |
|------------|---|
| Figure 1-1 | Locations of JPL Groundwater Monitoring Wells and Nearby Municipal Production Wells         |
| Figure 3-1 | Contours of Carbon Tetrachloride Concentrations in Aquifer Layer 1, January - February 2002 |
| Figure 3-2 | Contours of Carbon Tetrachloride Concentrations in Aquifer Layer 1, April - May 2002        |
| Figure 3-3 | Contours of Carbon Tetrachloride Concentrations in Aquifer Layer 1, July 2002               |
| Figure 3-4 | Contours of Carbon Tetrachloride Concentrations in Aquifer Layer 1, October - November 2002 |
| Figure 3-5 | Contours of Carbon Tetrachloride Concentrations in Aquifer Layer 2, January - February 2002 |

|             |   |
|-------------|---|
| Figure 3-6  | Contours of Carbon Tetrachloride Concentrations in Aquifer Layer 2, April - May 2002        |
| Figure 3-7  | Contours of Carbon Tetrachloride Concentrations in Aquifer Layer 2, July 2002               |
| Figure 3-8  | Contours of Carbon Tetrachloride Concentrations in Aquifer Layer 2, October - November 2002 |
| Figure 3-9  | Contours of Carbon Tetrachloride Concentrations in Aquifer Layer 3, January - February 2002 |
| Figure 3-10 | Contours of Carbon Tetrachloride Concentrations in Aquifer Layer 3, April - May 2002        |
| Figure 3-11 | Contours of Carbon Tetrachloride Concentrations in Aquifer Layer 3, July 2002               |
| Figure 3-12 | Contours of Carbon Tetrachloride Concentrations in Aquifer Layer 3, October - November 2002 |
| Figure 3-13 | Contours of Trichloroethene Concentrations in Aquifer Layer 1, January - February 2002      |
| Figure 3-14 | Contours of Trichloroethene Concentrations in Aquifer Layer 1, April - May 2002             |
| Figure 3-15 | Contours of Trichloroethene Concentrations in Aquifer Layer 1, July 2002                    |
| Figure 3-16 | Contours of Trichloroethene Concentrations in Aquifer Layer 1, October - November 2002      |
| Figure 3-17 | Contours of Trichloroethene Concentrations in Aquifer Layer 2, January - February 2002      |
| Figure 3-18 | Contours of Trichloroethene Concentrations in Aquifer Layer 2, April - May 2002             |
| Figure 3-19 | Contours of Trichloroethene Concentrations in Aquifer Layer 2, July 2002                    |
| Figure 3-20 | Contours of Trichloroethene Concentrations in Aquifer Layer 2, October - November 2002      |
| Figure 3-21 | Contours of Trichloroethene Concentrations in Aquifer Layer 3, January - February 2002      |
| Figure 3-22 | Contours of Trichloroethene Concentrations in Aquifer Layer 3, April - May 2002             |
| Figure 3-23 | Contours of Trichloroethene Concentrations in Aquifer Layer 3, July 2002                    |

|             |  |
|-------------|--|
| Figure 3-24 | Trichloroethene Concentrations in Aquifer Layer 3, October - November 2002               |
| Figure 3-25 | Contours of Tetrachloroethene Concentrations in Aquifer Layer 1, January - February 2002 |
| Figure 3-26 | Contours of Tetrachloroethene Concentrations in Aquifer Layer 1, April - May 2002        |
| Figure 3-27 | Contours of Tetrachloroethene Concentrations in Aquifer Layer 1, July 2002               |
| Figure 3-28 | Contours of Tetrachloroethene Concentrations in Aquifer Layer 1, October - November 2002 |
| Figure 3-29 | Contours of Tetrachloroethene Concentrations in Aquifer Layer 2, January - February 2002 |
| Figure 3-30 | Contours of Tetrachloroethene Concentrations in Aquifer Layer 2, April - May 2002        |
| Figure 3-31 | Contours of Tetrachloroethene Concentrations in Aquifer Layer 2, July 2002               |
| Figure 3-32 | Tetrachloroethene Concentrations in Aquifer Layer 2, October - November 2002             |
| Figure 3-33 | Contours of Tetrachloroethene Concentrations in Aquifer Layer 3, January - February 2002 |
| Figure 3-34 | Contours of Tetrachloroethene Concentrations in Aquifer Layer 3, April - May 2002        |
| Figure 3-35 | Contours of Tetrachloroethene Concentrations in Aquifer Layer 3, July 2002               |
| Figure 3-36 | Contours of Tetrachloroethene Concentrations in Aquifer Layer 3, October - November 2002 |
| Figure 3-37 | Contours of Perchlorate Concentrations in Aquifer Layer 1, January - February 2002       |
| Figure 3-38 | Contours of Perchlorate Concentrations in Aquifer Layer 1, April - May 2002              |
| Figure 3-39 | Contours of Perchlorate Concentrations in Aquifer Layer 1, July 2002                     |
| Figure 3-40 | Contours of Perchlorate Concentrations in Aquifer Layer 1, October - November 2002       |
| Figure 3-41 | Contours of Perchlorate Concentrations in Aquifer Layer 2, January - February 2002       |
| Figure 3-42 | Contours of Perchlorate Concentrations in Aquifer Layer 2, April - May 2002              |
| Figure 3-43 | Contours of Perchlorate Concentrations in Aquifer Layer 2, July 2002                     |

|             |  |
|-------------|--|
| Figure 3-44 | Contours of Perchlorate Concentrations in Aquifer Layer 2, October - November 2002                     |
| Figure 3-45 | Contours of Perchlorate Concentrations in Aquifer Layer 3, January - February 2002                     |
| Figure 3-46 | Contours of Perchlorate Concentrations in Aquifer Layer 3, April - May 2002                            |
| Figure 3-47 | Contours of Perchlorate Concentrations in Aquifer Layer 3, July 2002                                   |
| Figure 3-48 | Contours of Perchlorate Concentrations in Aquifer Layer 3, October - November 2002                     |
| Figure 5-1  | Annual Hydrograph for Deep, Multi-Port Well MW-3   |
| Figure 5-2  | Annual Hydrograph for Deep, Multi-Port Well MW-4   |
| Figure 5-3  | Annual Hydrograph for Deep, Multi-Port Well MW-11  |
| Figure 5-4  | Annual Hydrograph for Deep, Multi-Port Well MW-12  |
| Figure 5-5  | Annual Hydrograph for Deep, Multi-Port Well MW-14  |
| Figure 5-6  | Annual Hydrograph for Deep, Multi-Port Well MW-17  |
| Figure 5-7  | Annual Hydrograph for Deep, Multi-Port Well MW-18  |
| Figure 5-8  | Annual Hydrograph for Deep, Multi-Port Well MW-19  |
| Figure 5-9  | Annual Hydrograph for Deep, Multi-Port Well MW-20  |
| Figure 5-10 | Annual Hydrograph for Deep, Multi-Port Well MW-21  |
| Figure 5-11 | Annual Hydrograph for Deep, Multi-Port Well MW-22  |
| Figure 5-12 | Annual Hydrograph for Deep, Multi-Port Well MW-23  |
| Figure 5-13 | Annual Hydrograph for Deep, Multi-Port Well MW-24  |
| Figure 5-14 | Annual Hydrographs for Shallow Monitoring Wells MH-01, MW-5, MW-6, MW-7, MW-8, MW-10, MW-13, and MW-16 |
| Figure 5-15 | Annual Hydrographs for Shallow Monitoring Wells MW-1, MW-9, and MW-15                                  |
| Figure 5-16 | Typical Water-Table Elevation Contour Map (November 7, 2002)   |

Figure 6-1      Flow Chart Summarizing Potential Changes to Long Term Groundwater Sampling  
Frequencies

## ACRONYMS AND ABBREVIATIONS

|                    |   |
|--------------------|---|
| $\mu\text{g/L}$    | Micrograms per liter                          |
| 1,2-DCA            | 1,2-dichloroethane                            |
| AL                 | DHS action level                              |
| As                 | Arsenic                                       |
| $\text{Ca}^{2+}$   | Calcium                                       |
| $\text{CCl}_4$     | Carbon Tetrachloride                          |
| Cl <sup>-</sup>    | Chloride                                      |
| $\text{ClO}_4^-$   | Perchlorate                                   |
| COI                | Constituent of Interest                       |
| Cr                 | Chromium                                      |
| Cr(VI)             | Hexavalent Chromium                           |
| DHS                | (California) Department of Health Services    |
| DLR                | Detection Limit for the Purposes of Reporting |
| DTSC               | Department of Toxic Substances Control        |
| EPA                | U.S. Environmental Protection Agency          |
| Foster Wheeler     | Foster Wheeler Environmental Corporation      |
| FSAP               | Field Sampling and Analysis Plan              |
| $\text{HCO}_3^-$   | Bicarbonate                                   |
| JPL                | Jet Propulsion Laboratory                     |
| MCL                | Maximum contaminant level                     |
| $\text{mg/L}$      | Milligrams per liter                          |
| MW                 | Monitoring Well                               |
| $\text{Na}^+$      | Sodium  |
| NDMA               | n-nitrosodimethylamine                        |
| NTU                | Nephelometric turbidity unit                  |
| Pb                 | Lead  |
| PCE                | Tetrachloroethene (Perchloroethene)           |
| QA/QC              | Quality Assurance/Quality Control             |
| RWQCB              | Regional Water Quality Control Board          |
| $\text{SO}_4^{-2}$ | Sulfate                                       |
| SOTA               | SOTA Environmental Technology, Inc.           |
| TCE                | Trichloroethene                               |
| TDS                | Total Dissolved Solids                        |
| VOC                | Volatile Organic Compound                     |





## EXECUTIVE SUMMARY

This report summarizes the results from the sixth year of long-term quarterly groundwater monitoring for the National Aeronautics and Space Administration-Jet Propulsion Laboratory (JPL). The Long-Term Quarterly Groundwater Monitoring Program is part of the Comprehensive Environmental Response, Compensation and Liability Act Remedial Investigation/Feasibility Study and was initiated in August 1996 in response to a request from the U.S. Environmental Protection Agency (EPA). The purpose of this report is to compile and summarize the last year of monitoring data, evaluate the effectiveness of the monitoring system, and recommend adjustments to the monitoring program, if necessary. During this past year of monitoring, groundwater samples were collected quarterly from all 18 on-site JPL monitoring wells and from all five off-site JPL monitoring wells, and analyzed for organic and inorganic analytes.

Carbon tetrachloride, trichloroethene, 1,2-dichloroethane, and tetrachloroethene were the only volatile organic compounds detected in groundwater samples at concentrations in excess of State and/or Federal Maximum Contaminant Levels (MCLs) for drinking water. One inorganic constituent, perchlorate ( $\text{ClO}_4^-$ ) was detected in groundwater samples at concentrations exceeding the California Department of Health Services action level (AL) of 4 micrograms/liter. These compounds were generally detected at higher concentrations beneath the north-central portion of the site. Lower concentrations were generally detected to the south and east from the north-central portion of the site.

Arsenic (As) and lead (Pb) were rarely detected at concentrations well below State and Federal MCLs. Total chromium was detected in one sample from one on-site well at a concentration above the State MCL, but below the Federal MCL. Hexavalent chromium, for which State and Federal MCLs have not yet been established, was detected consistently only in on-site well MW-13. N-nitrosodimethylamine (NDMA) analysis was performed during the first quarterly event of 2002 on samples from selected wells, and was not detected. 1,4-Dioxane analyses were performed on samples from selected wells during the first quarterly event of 2002 and was detected in only one well at very low levels (near the detection limit).

Groundwater quality data suggest that the constituents of interest at JPL are well defined, and that VOC plumes are predominately stable. However, it is noted that  $\text{ClO}_4^-$  was detected for the first time in one location (MW-3 Screen 5, up to 140  $\mu\text{g/L}$ ) and increased above the  $\text{ClO}_4^-$  AL at another location (MW-18 Screen 4).

Three different general water types were identified beneath JPL as suggested by differences in the concentrations of major anions and cations. In general, very little change in water type with time has been observed since the monitoring program began six years ago. Water-elevation data collected during the year consistently showed that regional groundwater flow has been primarily towards the south and east.

Based on the approved plan, to identify monitoring points that yield redundant data, each sampling point was categorized relevant to each constituent of interest or plume (i.e., plume well, downgradient well, or upgradient well). Individual monitoring point classification allowed for adjustments in the sampling

program in which upgradient points (consistently showing non-detect) were sampled less frequently, thereby improving program efficiency.

To further modify the groundwater monitoring program, we propose that the classification of each well and well screen be based on a two year rolling calendar. Wells will be reclassified annually based on analytical results from the previous year, thereby keeping the monitoring program current with aquifer and plume conditions.

## 1.0 INTRODUCTION

This report summarizes the results from the sixth full year (January through October 2002) of quarterly groundwater monitoring completed as part of the Long-Term Quarterly Groundwater Monitoring Program at the National Aeronautics and Space Administration-Jet Propulsion Laboratory (JPL) for the Comprehensive Environmental Response, Compensation and Liability Act Remedial Investigation/Feasibility Study. The Long-Term Quarterly Groundwater Monitoring Program was initiated in response to a request from the U.S. Environmental Protection Agency (EPA) with the objective of monitoring hydrogeological conditions and the nature and extent of groundwater constituents beneath JPL. The purpose of this report is to compile and summarize the previous year's data, to evaluate the effectiveness of the monitoring program, and to recommend adjustments to the program, if necessary.

The monitoring program involves sampling of 23 groundwater monitoring wells (located both on- and off-site) and quantification of various analytes in the samples. Additionally, water-level data are collected at each well and used to monitor groundwater gradients and flow directions.

Locations of the JPL monitoring wells are shown in Figure 1-1. Monitoring wells MW-3, MW-4, MW-11, MW-12, MW-14 and MW-17 through MW-24 are deep, multi-port wells, each containing five screened intervals within a Westbay Instruments, Inc. (Westbay) multi-port casing system. Monitoring wells MW-1, MW-5, MW-6, MW-7, MW-8, MW-9, MW-10, MW-13, MW-15, and MW-16 are relatively shallow standpipe wells, each containing a single screened interval at the water table. Deep, multi-port wells MW-17, MW-18, MW-19, MW-20 and MW-21 are located off-site, while all other monitoring wells are located on-site (MW-3 is located just outside the eastern boundary of JPL, but is considered an "on-site" well). Shallow well MW-2 was replaced with deep multi-port well MW-14 as a JPL sampling point in 1996 and has not been sampled since. A summary of the JPL monitoring well construction details is given in Table 1-1.

The four quarterly groundwater sampling events that comprise the past monitoring year are designated as follows:

- January/February 2002
- April/May 2002
- July 2002
- October/November 2002

Monitoring points (wells and well screens) sampled and analyses conducted during these four events are identified in Table 1-2. Based on results from previous long-term quarterly monitoring, and guidelines included in the approved Long-Term Quarterly Monitoring Program Plan by Foster Wheeler Environmental Corporation (Foster Wheeler), adjustments were made to the Long-Term Monitoring Program during the fourth quarter of 1999 (Foster Wheeler, 1996a). These changes are noted in Table 1-2 and included:

- All JPL monitoring points were classified with respect to each constituent of interest (COI) [volatile organic compounds (VOCs), perchlorate ( $\text{ClO}_4^-$ ), total chromium (Cr), and hexavalent chromium ( $\text{Cr(VI)}$ )] as either being plume, downgradient or upgradient points based on previous analytical results and groundwater flow directions.
- Plume and downgradient points (with respect to each constituent) were sampled for the appropriate constituents.
- Upgradient points (with respect to each constituent) were not sampled.

Based on the approved Long-Term Quarterly Monitoring Program Plan (Foster Wheeler, 1996a) and on results from the first two years of long-term monitoring at JPL, it was proposed that the monitoring program be revised to improve monitoring efficiency. Approval was obtained from the regulatory agencies [EPA, California Department of Toxic Substances Control (DTSC) and the California Regional Water Quality Control Board (RWQCB)], and the proposed changes were implemented for the final quarterly event of 1999. Beginning in 2000, additional changes to the program plan as agreed to by the regulatory agencies were implemented as follows

- Analysis for lead (Pb), arsenic (As), 1,4-dioxane, and n-nitrosodimethylamine (NDMA) were performed annually due to infrequent detection.
- Analysis of general water chemistry parameters (major anion/cations) was also conducted annually based on the consistency of prior results (Foster Wheeler, 2000a).

Sampling procedures and the sampling QA/QC program are summarized in Section 2.0 of this report. All sampling records, field instrument calibration forms, laboratory analytical reports and chain-of-custody forms for each sampling event are included in the appendices of their respective quarterly reports (SOTA, 2002a,b,c, and 2003) and are not included in this summary report.

The analytical program focused on quantification of various constituents in the groundwater and determination of general water type based on general water quality analyses. Constituents of interest were monitored to determine the nature and extent of contamination in groundwater beneath JPL, and will be discussed in Section 3.0. The water-quality data were used to establish generalized groundwater types, and are discussed in Section 4.0.

In addition to water quality analyses, hydraulic-head measurements were recorded at each screen in the deep multi-port wells and water levels measured in the on-site shallow wells prior to and immediately following each quarterly event. These data are used to monitor both horizontal and vertical groundwater flow and is presented in Section 5.0.

Section 6.0, Well Reclassification, presents decision criteria for reduced monitoring frequency and analytes, and proposes revised analytical requirements for the groundwater monitoring program at JPL. Section 7.0 summarizes the findings of the previous year of groundwater monitoring and presents our conclusions, opinions, and recommendations regarding site conditions and proposed changes to the monitoring program. Section 8.0 provides selected references used in the preparation of this report.



## **2.0 SAMPLING AND FIELD QUALITY ASSURANCE/QUALITY CONTROL**

Two different procedures were used in the collection and handling of groundwater samples at JPL: one designed for the shallow wells, and the other for the deep multi-port wells. These procedures are briefly outlined below.

### **2.1 Shallow Monitoring Wells**

Dedicated submersible pumps were used to sample the shallow monitoring wells. The pumps were decontaminated prior to installation (Ebasco, 1993a). Prior to sampling, the water in each well casing was purged (by pumping) to remove groundwater that may have been exposed to the atmosphere and thus was not representative of aquifer conditions.

Temperature, pH, electrical conductivity and turbidity of the water were monitored during purging. After these parameters stabilized (when two successive measurements made approximately 3 minutes apart were within approximately 10 percent of each other) and the turbidity was less than 5 Nephelometric Turbidity Units (NTUs) or a minimum of three casing volumes had been purged, groundwater samples were collected directly from the discharge hose of the dedicated pump. A detailed description of the shallow well sampling procedure is included in the Field Sampling and Analysis Plan (FSAP) for Operable Unit-1 (on-site groundwater) (Foster Wheeler, 1993a).

All sample bottles were filled completely (not allowed to overflow), capped, labeled, and placed in a cooler with ice immediately after sample collection. Samples collected for VOCs had zero headspace.

### **2.2 Deep Multi-Port Monitoring Wells**

Sampling of the deep JPL multi-port monitoring wells required specialized sampling equipment manufactured by Westbay. This equipment included a pressure profiling/sampling probe with a surface control unit. Copies of the detailed operations manuals for the Westbay pressure profiling/sampling probe are available elsewhere (Ebasco, 1993a; 1994).

The Westbay sampling probe and sample bottles were decontaminated prior to sampling at each screened interval in each deep multi-port well. Purging before sampling is not required in the deep multi-port monitoring wells because the groundwater sample is collected directly from the aquifer, and is not exposed to the atmosphere. However, at each screened interval an initial sample of groundwater was collected in order to check pH, electrical conductivity, temperature, and turbidity and to rinse the Westbay stainless-steel sample collection bottles with formation water. Samples for laboratory analysis were then collected and transferred to sample containers as described in Section 2.1. A detailed description of the deep well sampling procedures is included in the FSAPs for Operable Unit-1 (on-site groundwater) and Operable Unit-3 (off-site groundwater) (Ebasco, 1993a and 1994).

### **2.3 Quality Assurance/Quality Control Procedures**

To verify the quality of the sampling procedures and analytical data, various field and laboratory QA/QC procedures were followed. These included collection of duplicate groundwater samples,

equipment blanks, trip blanks, source blanks, and field blanks during each quarterly sampling event. The laboratory QA/QC program (matrix spikes, surrogate compounds, method blanks, etc.) was conducted according to specific procedural and analytical method requirements. QA/QC program results for each quarter of monitoring are available in the quarterly groundwater monitoring reports for the past monitoring year (SOTA, 2002a,b,c, and 2003). QA/QC procedures are discussed in detail in the Quality Assurance Program Plan for completing the Remedial Investigation (Ebasco, 1993b) and associated addenda (Foster Wheeler, 1996b and 1998). Field QA/QC data (trip blanks, equipment blanks, and field blanks) have consistently shown that the sampling and sample handling procedures are not introducing contamination and, therefore, the data are acceptable for their intended use.



### 3.0 ANALYTICAL RESULTS - CONSTITUENTS OF INTEREST

The analytical results for the constituents of interest, which include VOCs,  $\text{ClO}_4^-$ , metals [Pb, As, total Cr, and Cr(VI)], NDMA, and 1,4-dioxane are summarized in this section. Refer to Section 1.0 and Table 1-2 for a summary of changes made to the monitoring program, and analyses performed during each of the four 2002 sampling events. Results from VOCs and  $\text{ClO}_4^-$  analyses are compiled in Table 3-1, and results for metals analyses are presented in Table 3-2. Refer to Figure 1-1 for monitoring well locations. General discussions of the analytical results are provided in the following sections. In these discussions, where State and Federal maximum contaminant levels for drinking water (MCLs) differ, the more stringent level is referenced.

#### 3.1 Volatile Organic Compounds Results

VOC results are summarized in Table 3-1. The key findings are listed below, and a more complete description is provided in the following paragraphs. The VOC results indicated the following:

- Only five VOCs were detected at concentrations exceeding their respective MCLs during 2002, including carbon tetrachloride ( $\text{CCl}_4$ ), trichloroethene (TCE), 1,2-dichloroethane (1,2-DCA), 1,1-dichloroethene (1,1-DCE), and tetrachloroethene (PCE). In general, the highest concentrations of VOCs were identified in the shallow portion of the aquifer (Aquifer Layer 1) beneath the central portion of JPL.
  - ? The  $\text{CCl}_4$  plume is generally limited to the site in Aquifer Layer 1 and is migrating off-site (laterally and vertically) downgradient into Aquifer Layers 2 and 3 south and east of JPL.
  - ? The TCE plume appears to be migrating south of JPL in Aquifer Layer 1. TCE was not reported above the MCL in Aquifer Layer 2, but was reported above the MCL in Aquifer Layer 3 at two off-site (downgradient) wells.
  - ? The 1,2-DCA and 1,1-DCE plumes appear to be associated with the TCE plume and are relatively minor in comparison.
  - ? The PCE plume is generally limited to the center of JPL and appears relatively stable. PCE was not reported above the MCL in Aquifer Layers 2 or 3, except at cross-gradient well MW-21.
- Except where noted below, trends regarding concentration and locations of detections were consistent with past sampling years.

#### Carbon Tetrachloride

Almost all of the  $\text{CCl}_4$  detections reported in 2002, including those in off-site wells, exceeded the State MCL (0.5  $\mu\text{g/L}$ ). During the past year of monitoring, relatively high concentrations of  $\text{CCl}_4$  have consistently been present in samples from on-site shallow well MW-7, located in the north central portion of the site, up to a high of 208 micrograms/liter ( $\mu\text{g/L}$ ) in April/May 2002. Lower concentrations of  $\text{CCl}_4$  (<15  $\mu\text{g/L}$ ) were reported during 2002 in samples from seven on-site wells and

two off-site wells. These lower concentrations were generally encountered in the south-central portion of JPL (downgradient from MW-7) in Aquifer Layer 1 and southeast of JPL in Aquifer Layers 2 and 3.

### **Trichloroethene**

Concentrations of TCE up to 47 µg/L (in excess of the State and Federal MCLs of 5.0 µg/L) were detected in samples from seven on-site wells and three off-site wells during 2002. On-site wells containing TCE concentrations exceeding the MCL were located in the central and south-central portions of JPL. Relatively lower TCE concentrations (below the MCL) were reported in samples from eight on-site wells and one off-site well, including on-site wells MW-6 and MW-14 which are located cross-gradient of the plume (to the west). TCE had been detected in on-site well MW-8 infrequently during the previous three years and was reported above the MCL during the last quarterly event of 2002. Two of the three off-site wells containing TCE above the MCL (MW-17 and MW-18) are located downgradient (to the southeast) of JPL, and the other (MW-21) is located cross-gradient (to the southwest) of JPL.

### **1,2-Dichloroethane**

1,2-DCA was only detected in on-site well MW-24, at an estimated concentration equal to the State MCL (0.5 µg/L) in January/February 2002. This compound was not detected during the subsequent two events (April/May and July 2002) and was reported below the MCL in October/November 2002. 1,2-DCA was not detected in any other on-site or off-site monitoring well during 2002.

### **1,1-Dichloroethene**

1,1-DCE was found at concentrations exceeding the State MCL (0.5 µg/L) in samples from on-site well MW-7, and below the MCL in on-site wells MW-13 and MW-16. 1,1-DCE was not detected in any off-site monitoring well. At MW-7, 1,1-DCE was reported above the MCL three of the last four monitoring events with concentrations ranging from 3.1 µg/L to 12.4 µg/L.

### **Tetrachloroethene**

Concentrations of PCE exceeded the State and Federal MCL (5 µg/L) in two on-site wells (MW-6 and MW-7) and two off-site wells (MW-18 and MW-21) during the past year of monitoring. On-site well MW-7 is located in the central portion of JPL, while well MW-6 is located cross-gradient of the plume in the western portion of JPL. Off-site well MW-21 is located cross-gradient of the plume (south of JPL) while well MW-18 is located downgradient of the plume (southeast of JPL). PCE was detected at concentrations below the MCL in 11 on-site wells, and three off-site wells. The on-site wells in which PCE was detected below the MCL were generally located in the western portion of the site. Off-site wells in which PCE was detected (MW-17, MW-18, MW-19, and MW-20) were located downgradient (east and southeast of JPL), except for well MW-21, which is located south of JPL and cross-gradient of the plume.

## Other VOCs

Other VOCs have been detected in JPL groundwater samples, but these have either been at concentrations well below MCLs, or the detections have been exceedingly rare or attributable to laboratory contamination (see Table 3-1).

### 3.2 Perchlorate Results

$\text{ClO}_4^-$  is generally present beneath the central and south-central portions of the site, and off-site in the southeasterly direction. During the past year of monitoring, groundwater samples from 13 on-site wells and four off-site wells contained  $\text{ClO}_4^-$  at concentrations exceeding the California Department of Health Services action level (AL) of 4  $\mu\text{g/L}$ . Higher concentrations were generally reported on-site in the shallower portion of the aquifer, and lower concentrations were generally reported off-site (downgradient), in deeper portions of the aquifer. One of the wells containing  $\text{ClO}_4^-$  (MW-21) is located cross-gradient of JPL to the southwest, and two of the wells (MW-14 and MW-6) are located upgradient.  $\text{ClO}_4^-$  was not detected in samples from four on-site wells located near the mouth of the Arroyo and one off-site well (MW-19) located south of JPL.

Perchlorate concentrations exceeding the AL were reported three out of the four events in the farthest downgradient well (MW-20), at Screen 1 in January/February and at Screen 4 in April/May and October/November, with concentrations up to 58.5  $\mu\text{g/L}$ . Previously, perchlorate had been rarely detected at this well at much lower concentrations.

### 3.3 1,4-Dioxane and NDMA Results

Groundwater samples from six selected locations (MW-4 Screen 2, MW-7, MW-13, MW-16, MW-17 Screen 3, and MW-24 Screen 1) were analyzed for 1,4-dioxane during the first quarter of the past year of monitoring (i.e., January 2002). The selected wells historically contained the highest concentrations of groundwater constituents at JPL.

NDMA was not detected above the laboratory reporting limit (0.002  $\mu\text{g/L}$ ) in any of the groundwater samples collected. No State or Federal MCLs have been established for NDMA. The current drinking water AL for NDMA is 0.01  $\mu\text{g/L}$ .

1,4-Dioxane was reported at concentrations ranging from 3 to 10  $\mu\text{g/L}$  in samples from four on-facility wells (MW-7, MW-16, MW-13, and MW-24), generally consistent with the previous results. At this time, neither State nor Federal MCLs have been established for 1,4-dioxane. The current drinking water AL for 1,4-dioxane is 3  $\mu\text{g/L}$ .

### 3.4 Metals Results

Metals data are summarized in Table 3-2, and include the results for As, Pb, total Cr, and Cr(VI), which are discussed below.

Lead was detected in two samples that were collected during the January-February 2002 event (MW-12 Screen 5 and MW-17 Screen 5, with concentrations of 0.0011 mg/L and 0.0028 mg/L, respectively). Neither of the reported lead concentrations exceeded the State MCL (0.05 mg/L) or the Federal MCL (0.1 mg/L). Arsenic was detected in four on-facility wells (MW-3, MW-5, MW-12, and MW-23) and one off-facility well (MW-17), with concentrations ranging from 0.0014 mg/L to 0.0047 mg/L. None of the reported arsenic concentrations exceeded the State and Federal MCL of 0.05 mg/L. These metals occur naturally in JPL soils (Foster Wheeler, 1999e), and their presence in JPL groundwater is believed to have resulted from natural processes.

Total chromium was detected in all wells except MW-1 and MW-9, including fourteen on-facility wells and three off-facility wells (MW-18, MW-19, and MW-21) during 2002. Total chromium concentrations only exceeded State and Federal MCLs (0.05 and 0.10 mg/L, respectively) in on-facility wells MW-6 and MW-13.

Hexavalent chromium was detected in one on-facility well (MW-13) during 2002, at concentrations ranging from 0.028 to 0.120 mg/L. At this time, Federal regulatory agencies have not established an MCL for hexavalent chromium. Hexavalent chromium is currently regulated by the State under the MCL for total chromium (0.05 mg/L), which was exceeded in three of the four detections at well MW-13 during 2002.

### 3.5 Production Well Data

Readily available analytical results for the VOCs of interest and perchlorate were obtained from the California Department of Health Services (CA DHS) Drinking Water Program for samples collected from the municipal production wells located near JPL. Data were compiled for the 15 municipal and private drinking water wells, which are owned and operated by the City of Pasadena, La Canada Irrigation District (LCID), Lincoln Ave. Water Company (LAWC), Valley Water Company (VWC), Rubio Canon Land & Water Company (RCL&WC), and Las Flores Water Company (LFWC). The City of Pasadena, LAWC, RCL&WC, and LFWC wells are located generally southeast and downgradient of JPL, while the LCID and VWC wells are located west and upgradient of JPL. Refer to Figure 1-1 for production well locations. Production well data obtained during the last two years of the long-term monitoring program, summarized in Table 3-3, indicate the following:

- $\text{CCl}_4$  was not detected in any of the production wells except for at City of Pasadena Well #52.  $\text{CCl}_4$  concentrations at Well #52 were reported above the MCL of 0.5  $\mu\text{g/L}$  in all three samples collected during 2002 (up to 2.3  $\mu\text{g/L}$ ).  $\text{CCl}_4$  concentrations have previously been reported above the MCL of at the City of Pasadena Arroyo Well, which was deactivated in 1999.
- TCE concentrations were reported below the MCL (5.0  $\mu\text{g/L}$ ) at all of the municipal production wells sampled in 2002. TCE was detected (below the MCL) in samples from all of the City of Pasadena Wells, both LAWC wells, and two of the four VWC wells (#1 and #3). Only one production well has previously been reported to contain TCE concentrations exceeding the MCL (LAWC Well #3, with 5.4  $\mu\text{g/L}$  in September 2001).

- PCE concentrations were reported above the MCL (5.0 µg/L) at LFWC Well #2, ranging from 12 to 15 µg/L, all four quarterly sampling events in 2002. PCE was detected below the MCL at all three active City of Pasadena wells and all but one of the upgradient production wells (LCID and VWC). PCE concentrations were reported near the MCL in 2002 at VWC Wells #1 and #3 (4.1 and 4 µg/L, respectively). Samples collected in 2001 from VWC Wells #1, #2, & #3 contained PCE concentrations exceeding the MCL.
- During 2002, perchlorate concentrations exceeded the action level (AL) of 4 µg/L at all three active City of Pasadena Wells (Well #52, Ventura Well, and Windsor Well), LAWC Well #5, VWC Well #1, RCL&WC Well #4, and LFWC Well #2, ranging from 4.2 to 23.25 µg/L. Perchlorate was also reported above the AL at VWC Wells #2, #3, and #4 in 2001, but was not detected in 2002.

### 3.6 Summary of Results

Results described above are summarized as follows.

- During 2002, the VOCs detected and their concentrations were generally consistent with those observed in previous years. On-site shallow wells contained relatively higher concentrations of VOCs than off-site JPL wells. Concentrations of these compounds above the MCLs have been, and continue to be, generally limited to groundwater beneath the JPL facility in Aquifer Layer 1, with one exception; the CCl<sub>4</sub> and TCE plumes appear to have migrated south and east of JPL in Aquifer Layers 2 and 3. During 2002, CCl<sub>4</sub> was reported above the MCL at one municipal production well and PCE was reported above the MCL at one municipal production well. TCE was not reported above the MCL at any of the production wells during 2002.
- ClO<sub>4</sub><sup>-</sup> concentrations above the AL generally appear limited to the JPL facility in Aquifer Layer 1 (Figure 3-1), but have migrated south and east of JPL in Aquifer Layers 2 and 3. Seven municipal production wells were reported to contain ClO<sub>4</sub><sup>-</sup> concentrations above the AL during 2002, all but one of which are located downgradient of JPL.
- As in previous years, As and Pb were rarely and randomly detected at low concentrations (all below their respective MCLs), and are believed to be naturally occurring.
- NDMA was not detected in any of the selected wells, consistent with previous results.
- 1,4-dioxane was detected in four on-site wells (MW-7, MW-13, MW-16, and MW-24 Screen 1) at concentrations ranging from 3 µg/L to 10 µg/L, generally consistent with the previous results. All reported detections were equal to or exceeded the AL of 3 µg/L.

## 4.0 GENERAL WATER CHEMISTRY

Based on the relative consistency of the general chemistry throughout the Long-Term Monitoring Program, sampling for these parameters is now conducted on an annual basis, as agreed to by the EPA, DTSC and RWQCB. As part of the monitoring program, groundwater samples were submitted for analysis of general groundwater parameters for the first quarter of the past year of monitoring (Table 1-2).

Analysis of general groundwater parameters included major cations and anions [sodium  $\text{Na}^+$ , potassium, calcium ( $\text{Ca}^{2+}$ ), magnesium, sulfate ( $\text{SO}_4^{2-}$ ), nitrate, chloride ( $\text{Cl}^-$ ), carbonate, bicarbonate ( $\text{HCO}_3^-$ )], total iron, Total Dissolved Solids (TDS), and pH. These analyses were performed in order to further understand the natural chemistry of the groundwater beneath JPL and for potential use in interpreting groundwater flow patterns. QA/QC checks were performed each quarter on the general chemistry data to determine that the data were acceptable for its intended use. General groundwater chemistry data for the January 2002 monitoring event are presented in Table 4-1.

The water chemistry results were summarized using Stiff diagrams, which allowed for a general empirical classification of each sample. This analysis has suggested that the majority of groundwater sampled at JPL can be classified as one of three general water types, based on the predominant cation and anion(s). These types include:

- Type 1 Calcium-bicarbonate groundwater:  $\text{Ca}^{2+}$  as the dominant cation and  $\text{HCO}_3^-$  as the dominant anion;
- Type 2 Sodium-bicarbonate groundwater:  $\text{Na}^+$  as the dominant cation and  $\text{HCO}_3^-$  as the dominant anion;
- Type 3 Calcium-bicarbonate/chloride/sulfate groundwater:  $\text{Ca}^{2+}$  as the dominant cation and  $\text{HCO}_3^-$  as the dominant anion, but with relatively elevated  $\text{Cl}^-$  and  $\text{SO}_4^{2-}$  concentrations.

In several cases, the data suggested possible blending of water types. It should be noted that there is some subjectivity inherent in this type of analysis. We can therefore make the assumption that the apparent blends may be classifiable as either water type represented. The 2002 results generally correspond well with the results from previous years, and indicate that water types are well characterized and consistent in terms of general groundwater chemistry. The groundwater classification results for 2002 and previous years are compiled in Table 4-2.

## 5.0 WATER-LEVEL MEASUREMENTS

Water level measurements were recorded before and after each quarterly sampling event to evaluate groundwater flow directions and gradients beneath and adjacent to JPL. Water levels in the shallow wells were measured using a Solinst water level meter. In the deep multi-port wells, the hydraulic head at each sampling port was measured with a Westbay pressure-transducer probe. Details of water level measurement procedures have previously been described (Ebasco, 1993a, 1994). The water-level measurement data is provided in each of the 2002 quarterly reports (SOTA, 2002a,b,c, and 2003) and summarized in Table 5-1.

Hydrographs generated from the water-level data collected manually from the deep multi-port wells are presented in Figures 5-1 through 5-13. Hydrographs generated from water-level data collected from the shallow wells are presented in Figures 5-14 and 5-15.

Data shown on Figures 5-1 through 5-14 indicate a general increase in water levels from January until May, followed by a general decrease in water levels from May until October and another increase in November. In contrast, data for shallow wells MW-1, MW-9, and MW-15 (shown in Figure 5-15), located near the mouth of the Arroyo Seco, indicate a slight increase in water levels from January to February followed by a steady decrease throughout the remainder of the year.

These data suggest that the aquifer layers are somewhat connected and influenced to a certain extent by pumping activities at nearby municipal production wells. As previously reported, a downward vertical component may be present due largely to pumping by the nearby City of Pasadena municipal production wells (Foster Wheeler, 2000). This vertical component is apparent in the hydrographs for most wells, particularly those near one or more production wells.

As part of the quarterly monitoring program, water levels taken immediately prior to and after each sampling event were contoured to evaluate groundwater flow directions during sampling. These water-elevation contour maps are included in each associated monitoring report and indicate that flow is primarily to the south and east across JPL. In addition, the maps show the continuous presence of a significant groundwater mound located at the mouth of the Arroyo Seco. This typical scenario is illustrated in Figure 5-16, which depicts typical groundwater elevation contours and flow directions that are representative of those observed.

## 6.0 MONITORING PROGRAM EVALUATION

Based on results from the Long-Term Quarterly Monitoring Program, and the guidelines included in the Long-Term Quarterly Monitoring Program Plan (Foster Wheeler, 1996b), adjustments were made to the existing monitoring program with the goal of optimizing sampling and monitoring efficiency. These changes consisted of classifying JPL monitoring points (wells and well screens) based on their proximity to the various groundwater contamination plumes (VOC and  $\text{ClO}_4^-$ ). This was carried out using the classification categories described in the Long-Term Monitoring Program Plan (Foster Wheeler, 1996b) as summarized below:

1. *Plume Wells*: Wells or well screens where constituents have been detected above the MCL or AL in the past. If a constituent was exceeded its respective MCL/AL anytime during the last two years of the long-term monitoring program, it was classified as a plume well.
2. *Downgradient and Cross-Gradient Wells*: Wells or well screens that lie near the “edge” of plumes where constituents have not been detected above MCL or AL during the last two years of the monitoring program, but may appear in the future. Multi-port well screens located immediately above or below a plume well screen were generally considered “downgradient” well screens if they had a lower hydraulic head than the adjacent plume well screen.
3. *Upgradient Wells*: Wells or well screens that are not likely to be in the path of contaminant plumes. Upgradient wells primarily provide background information.

The classification of the monitoring points allowed for adjustments in the sampling program in which upgradient points (consistently showing non-detect) would be sampled less frequently, thereby improving program efficiency. Changes were implemented using this system during the final quarter of 1999. To make groundwater monitoring more efficient, Foster Wheeler proposed to continue reclassification of all monitoring points quarterly with respect to each constituent. Monitoring points would be reclassified using analytical results from the previous eight quarters. This would result in decreasing the sampling frequency of monitoring points consistently showing non-detectable concentrations of constituents of interest, and increasing the sampling frequency of wells which had previously been non-detect but currently indicating detectable concentrations.

The previous two years of data were evaluated using previously established and approved criteria (Foster Wheeler, 1996a). The criteria were developed as a formal means of making modifications to the groundwater monitoring program. Based on our review of the previous two years of data, it was determined that the monitoring frequency and analytes may be reduced to provide a more efficient sampling approach while still meeting the data quality objective established for this study and without compromising program quality or effectiveness. The application of the criteria resulted in a reduction of the sampling frequency for VOC and perchlorate analyses at several wells. Specific revisions not addressed in the Foster Wheeler criteria include evaluation of non-plume analytes including lead, arsenic, NDMA, and general minerals.



## **6.1 Modification of Sampling Frequency for Plume Analytes**

The flowchart presented in Figure 6-1 provides decision criteria that were used along with the previous two years of monitoring data to evaluate the monitoring frequency for plume analytes (i.e., VOCs and perchlorate). The JPL groundwater monitoring wells were each evaluated with respect to the previous two years of monitoring data and classified as either a plume well, upgradient well, downgradient well, or cross-gradient well (Tables 6-2 and 6-3) for each constituent of interest (COI). Wells located generally up gradient of the municipal production wells were considered to be on the receptor path for the purpose of this evaluation.

Based on our review of the data and application of the decision criteria, the following changes in sample frequency for VOCs and perchlorate were considered.

### **Quarterly Sampling**

Wells downgradient from the plume where the COI was not ND for four consecutive rounds and was on the receptor path would be sampled quarterly.

### **Semi-Annual Sampling**

Four scenarios resulted in a semi-annual sampling schedule: 1) plume wells with highly variable data, 2) wells cross-gradient from the plume and not downgradient from other plume(s) where the COI was not ND for four consecutive rounds, 3) downgradient wells which were not ND for four consecutive rounds and not on the receptor path, and 4) downgradient wells which were ND for four consecutive rounds and on the receptor path.

### **Annual Sampling**

Two scenarios result in annual sampling: 1) wells upgradient of the plume and not downgradient from other plume(s), and 2) plume wells where the data was not highly variable.

### **Omit Analyte**

Wells cross-gradient from the plume and not downgradient from other plume(s), where the COI was ND for four consecutive rounds would not be sampled for that COI.

The revised analytical requirements for the groundwater monitoring program at JPL, following the Foster Wheeler decision criteria, are presented in Table 6-3 along with a comparison of previous and revised monitoring frequencies.

## **6.2 Modification of Sampling Frequency for Non-Plume Analytes**

In addition to modification of sampling frequencies for plume analytes, data for non-plume analytes (e.g., metals) were evaluated in an effort to optimize sampling and monitoring efficiency. Proposed changes in sampling frequency for these analytes are discussed below.

- ? Previous detections for total and hexavalent chromium in groundwater do not suggest the presence of a chromium plume in groundwater underneath JPL. Except for five wells (MW-4 Screen 2, MW-6, MW-7, MW-13, and MW-16), the detected concentrations of total chromium are very low compared to the MCL. If total chromium was detected above the MCL in the past and/or hexavalent chromium was detected, that well or well screen will be sampled semiannually and analyzed for both total and hexavalent chromium. Following this decision rule, five wells (MW-4 Screen 2, MW-6, MW-7, MW-13, and MW-16) will be sampled semiannually and analyzed for total chromium and hexavalent chromium. All remaining wells and well screens will continue to be sampled annually and analyzed for total chromium, and hexavalent chromium.
- ? During 2002, 1,4-dioxane was reported at trace concentrations in samples from four on-facility wells (MW-7, MW-16, MW-13, and MW-24), generally consistent with the previous results. All reported detections were equal to or exceeded the AL of 3 µg/L. For future sampling, 1,4-dioxane should continue to be analyzed for only at wells/screens with previous detections [i.e., MW-4 (Screen 2), MW-7, MW-13, MW-16, MW-17 (Screen 4), and MW-24 Screen 1].
- ? Arsenic and lead have been detected on an infrequent basis, consistently below the MCLs, and have displayed no significant upward trends in concentration over time. Additionally, lead and arsenic were detected in upgradient wells MW-6 and MW-14 (Screen 5). Therefore, lead and arsenic could be eliminated from the monitoring program without compromising program objectives.
- ? NDMA was not detected in any of the groundwater samples collected from the wells selected to monitor any conceivable plume. Therefore, NDMA could be eliminated from the monitoring program without compromising program objectives.
- ? The general mineral data were adequate to understand the natural chemistry of the groundwater beneath JPL and for interpreting groundwater flow patterns. The data remain viable for the design of treatment systems, if required. Since the general chemistry (major cations and anions) results have been generally consistent with previous results, it is not likely that any new information will be gained by continued monitoring of general chemistry. Therefore, general chemistry analyses could be eliminated from the groundwater-monitoring program at JPL without compromising program objectives.

The revised sampling frequencies for these analytes are presented in Table 6-3 along with a comparison of previous and revised monitoring frequencies.

## 7.0 CONCLUSIONS AND RECOMMENDATIONS

Evaluation of the previous two years of groundwater monitoring data suggest that the constituents of interest at JPL are generally well defined by the current network of monitoring wells, except for perchlorate, which was detected the farthest downgradient well (MW-20) twice during 2002. The following conclusions are based upon interpretation of analytical data and field measurements collected during the past year of the JPL Long-Term Quarterly Monitoring Program:

### VOCs

During four 2002 sampling events,  $\text{CCl}_4$ , TCE, 1,2-DCA, and PCE were the only volatile organic compounds detected in groundwater samples at concentrations in excess of Federal and/or State MCLs for drinking water. One municipal production well was reported to contain  $\text{CCl}_4$  concentrations above the MCL and one municipal production well was reported to contain PCE concentrations above the MCL during 2002. No wells were reported to contain TCE concentrations that exceeded the MCL during 2002. The VOC plumes appear to be migrating into deeper aquifer layers south and east of JPL, although they remain relatively well defined and generally stable.

### Perchlorate

Perchlorate was detected in groundwater samples collected during 2002 at concentrations exceeding the AL of 4 micrograms/liter. These compounds were generally reported at higher concentrations beneath the north-central portion of the site. Seven municipal production wells were also reported to contain perchlorate concentrations above the MCL during 2002, six of which are located downgradient of JPL. The perchlorate plume appears to be migrating into deeper aquifer layers south and east of JPL, although it remains relatively well defined and generally stable. However, perchlorate was detected twice during 2002 in the farthest down gradient well (MW-20), and the down gradient edge of the plume may be migrating beyond the current network of monitoring wells.

### Metals

Total chromium was detected in one sample from one on-site well at a concentration above the State MCL, but below the Federal MCL. Hexavalent chromium, for which State and Federal MCLs have not yet been established, was detected consistently only in on-site well MW-13. Arsenic and lead were rarely detected at concentrations well below State and Federal MCLs.

### NDMA and 1,4-Dioxane

NDMA analysis was performed during the first quarterly event of 2002 on samples from selected wells and was not detected in any of the selected samples. 1,4-dioxane analyses were performed on samples from selected wells during the first quarterly event of 2002 and was detected in only one well at very low levels (near the detection limit), but equal to or exceeding the AL of 3  $\mu\text{g/L}$ .

## **General Chemistry**

General water chemistry analyses indicate well-defined and relatively stable groundwater chemistry beneath JPL. The groundwater flow continues to be generally to the south and east across JPL. A downward vertical component may also be present, due largely to interconnecting aquifer layers and pumping by the nearby municipal production wells.

Based on the previously approved plan (Foster Wheeler, 1996a), an evaluation of the last two years of data was performed to identify monitoring points that yield redundant data. Each sampling point was categorized relevant to each constituent of interest or plume (i.e., plume, downgradient, cross-gradient, or upgradient well). Individual monitoring point classification allowed for adjustments in the sampling program in which upgradient and cross-gradient points (consistently showing non-detect), as well as plume wells without highly variable data, could be sampled less frequently, thereby improving program efficiency without compromising program objectives.

We recommend that the resulting revisions in monitoring frequency be adopted, with the following exceptions: 1) well MW-17 Screens 2, 3, and 4, and well MW-20 Screens 2 and 4 should continue to be analyzed for VOCs on a quarterly basis, and 2) well MW-17 Screens 2 and 3, well MW-19 Screens 2, 3, and 4, and well MW-20 Screens 2, 3, and 4 should continue to be analyzed for perchlorate on a quarterly basis. It is our opinion that quarterly sampling for these COIs should continue based on their proximity to both the plumes and municipal production wells. The proposed changes in sampling frequency are presented in Table 6-3. Implementation of the proposed sampling frequencies for VOCs and perchlorate would result in the following changes to the monitoring program:

### **VOCs**

- 1 sample location revised from annual to quarterly sampling
- 3 sample locations revised from annual to semi-annual sampling
- 2 sample locations revised from annual sampling to omitted
- 35 sample locations revised from quarterly to semi-annual sampling
- 9 sample locations revised from quarterly to annual sampling
- 3 sample locations revised from quarterly sampling to omitted
- 22 sample locations remained unrevised.

### **Perchlorate**

- No sample locations revised from annual to quarterly sampling
- 2 sample location revised from annual to semi-annual sampling
- 2 sample locations revised from annual sampling to omitted
- 25 sample locations revised from quarterly to semi-annual sampling
- 20 sample locations revised from quarterly to annual sampling
- 5 sample locations revised from quarterly sampling to omitted
- 21 sample locations remained unrevised.

In addition to the above changes in the sampling plan, the following additional changes (also shown in Table 6-3) are recommended:

- Arsenic and lead should be eliminated from the monitoring program, since these constituents have only been detected on an infrequent basis (consistently below the MCLs), displayed no significant upward trends in concentration over time, and were detected in upgradient wells MW-6 and MW-14 (Screen 5).
- NDMA should be eliminated from the monitoring program, since it was not detected during the last two years of monitoring in any of the groundwater samples collected from the wells selected for monitoring.
- No changes are recommended for 1,4 dioxane, which should continue to be analyzed for at 6 sampling locations.
- Routine general chemistry analyses should be eliminated from the groundwater monitoring program. The previous general mineral data are considered adequate to understand the natural chemistry of the groundwater beneath JPL and for interpreting groundwater flow patterns. The data remains viable for the design of treatment systems, if required. Since the general chemistry (major cations and anions) results have been generally consistent with previous results, it is not likely that any new information will be gained by continued monitoring of general chemistry.
- The groundwater monitoring program should be periodically reevaluated based on changing needs for data. It is recommended that data from each well and well screen be reviewed based on analytical results from the previous two years and the best understanding of current aquifer and plume conditions.
- We further recommend that additional wells be constructed to act as downgradient monitoring wells for the perchlorate plume and sampled quarterly for a minimum of two years.

## 8.0 REFERENCES

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